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Toxicity of Fenvalerate and Permethrin to
Several Nontarget Aquatic Invertebrates

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Toxicity of Fenvalerate and Permethrin to Several Nontarget Aquatic Invertebrates¹

RICHARD L. ANDERSON

U.S. Environmental Protection Agency, Environmental Research Laboratory-Duluth, 6201 Congdon Boulevard, Duluth, Minnesota 55804

ABSTRACT

Environ. Entomol. 11: 1251-1257 (1982)

Selected species of stoneflies, caddisflies, mayflies, dipterans, amphipods, and snails were exposed, in the laboratory, to fenvalerate or permethrin in a flowing-water test system for up to 28 days. Both behavior and death were monitored during the exposure. The LC_{50} values decrease with increasing exposure time. Behavior changes or death were seen at concentrations as low as 0.022 $\mu\text{g/liter}$ for fenvalerate and 0.030 $\mu\text{g/liter}$ for permethrin. In the fenvalerate exposures, amphipods were the most sensitive, followed by the insects and snails. In the permethrin exposures, changes in normal behavior occurred within hours, but death did not exceed 50% until at least 14 days of exposure. Pesticide accumulation was determined in fenvalerate-exposed snails and permethrin-exposed stoneflies. The range of accumulated fenvalerate in snails was 177 to 1,286 times greater than water concentration. The stoneflies' concentration factor for permethrin ranged from 43 to 570.

During the last 6 years, several of the photostable synthetic pyrethroid pesticides have been found to be highly toxic to larval mosquitoes (Mulla and Darwazeh 1976, Mulla et al. 1978a, Mulla et al. 1980) and blackflies (Muirhead-Thomson 1977). For example, the range of 24-h LC_{50} values for six mosquito species exposed to permethrin and fenvalerate is 0.50 to 3.00 $\mu\text{g/liter}$ and 0.9 to 28 $\mu\text{g/liter}$, respectively (Mulla et al. 1980). For blackflies, permethrin concentrations of 1 $\mu\text{g/liter}$ for 1 h can result in 60% mortality (Muirhead-Thomson 1977).

During this same time period, laboratory exposures of other aquatic invertebrates and fish have shown that synthetic pyrethroids may be equally toxic to nontarget animals. A permethrin exposure of 1 $\mu\text{g/liter}$ for 1 h resulted in a 64 to 93% mortality of *Gammarus*, *Brachycentrus*, or *Baetis* (Muirhead-Thomson 1978). Newly hatched and juvenile crayfish, *Procambarus clarkii*, 96-h LC_{50} values for permethrin are 0.39 and 0.62 $\mu\text{g/liter}$ (Jolley et al. 1978). Fish exposures have shown that 4-day LC_{50} values for permethrin are less than 10 $\mu\text{g/liter}$ for channel catfish, *Ictalurus punctatus*, largemouth bass, *Micropterus salmoides*, rainbow trout, *Salmo gairdneri*, and brook trout, *Salvelinus fontinalis* (Jolley et al. 1978, Kumaraguru and Beamish 1981, Johnson and Finley 1980). Another report compares fish and mosquito toxicity values for six synthetic pyrethroids (Mulla et al. 1978a). Four of the six pesticides had safety margins (ratio fish LC_{50} /mosquito LC_{50}) of 10 to >200 for the four fish species. Two (permethrin and Pydrin) had ratios of <1 to 3 for the desert pupfish, *Cyprinodon macularis*, and rainbow trout.

These studies have shown that some synthetic pyrethroid pesticides are acutely toxic to certain species at concentrations of <10 $\mu\text{g/liter}$. An assessment of the impact of these chemicals on nontarget invertebrates is restricted by the absence of two types of information. First, only one of the studies (Kumaraguru and Beamish

1981) measured the chemical in the water. Measurement of the chemical is important, since Sharom and Solomon (1981) have shown that adsorption and desorption of permethrin is affected by factors such as container material and size, and exposure time. A second factor is that all of the reported studies only exposed the animals for up to 4 days. The effect of long exposures at low concentrations has not been documented. The objective of this study was to determine, in a laboratory setting with measured concentrations, the long-term (up to 28 days) effects of the synthetic pyrethroid pesticides fenvalerate and permethrin on the behavior and survival of six species of aquatic invertebrates.

Materials and Methods

Test Animals

The animals used in this study were collected from streams or ponds in the Duluth, Minn., area. Snails and amphipods were maintained in the laboratory several months before they were used in the test. Reproduction occurred in both colonies. Adult, juvenile, and small juvenile (1 to 3 mm) amphipods were used in the fenvalerate exposures. Because of their size, the small juveniles were exposed in a static test system. The flow-through test was done with the larger amphipods grouped as an adult-juvenile stage. All other animals were acclimated to the test temperature for at least 1 week before testing. The animals used in these tests were the stonefly *Pteronarcys dorsata*, the mayfly *Ephemerella* sp., the caddisfly *Brachycentrus americanus*, the Rha-gionid fly *Atherix*, the snail *Heliosoma trivolvis*, and the amphipod *Gammarus pseudolimnaeus*. The invertebrates *P. dorsata*, *Ephemerella*, *Atherix*, and *G. pseudolimnaeus* were maintained before and during the exposure on a diet of birch and poplar leaves collected in the autumn and soaked in lake water. The caddisfly was maintained on diet of thawed adult brine shrimp. Snails were maintained on soaked leaves and thawed adult brine shrimp.

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Exposure System

The flow-through tests were conducted in an enclosed box which contained a toxicant generation system modelled after one described by Veith and Comstock (1975), a serial dilution system (Benoit et al. 1982) and the flow-through exposure test chambers. The dilution system delivered five concentrations and a control to duplicate exposure chambers. The fenvalerate concentrations ($\mu\text{g/liter}$, $\bar{x} \pm \text{SD}$) were as follows: for the *Ephemerella* sp. and *G. pseudolimnaeus* exposure, 0.93 ± 0.18 , 0.32 ± 0.12 , 0.12 ± 0.02 , 0.046 ± 0.008 , 0.022 ± 0.006 ; for *P. dorsata*, 1.02 ± 0.24 , 0.44 ± 0.06 , 0.17 ± 0.05 , 0.11 ± 0.03 , and 0.075 ± 0.013 ; for *Atherix* and *H. trivialis*, 0.79 ± 0.06 , 0.34 ± 0.17 , 0.13 ± 0.07 , 0.054 ± 0.030 , 0.021 ± 0.009 . The permethrin concentrations were 0.52 ± 0.14 , 0.22 ± 0.09 , 0.12 ± 0.05 , 0.064 ± 0.024 , and 0.030 ± 0.010 $\mu\text{g/liter}$ for *Brachycentrus* sp., and 0.43 ± 0.20 , 0.21 ± 0.10 , 0.12 ± 0.04 , 0.042 ± 0.019 , and 0.029 ± 0.016 $\mu\text{g/liter}$ for *P. dorsata*. The flow rate was 1,800 ml/h to each 1,600-ml test chamber. Fluorescent bulbs provided a light intensity of 18 to 29 ft-candles (ca. 193.7 to 312 lux) at the water surface. The lights were automatically controlled at a photoperiod of 14 h of light.

Unfiltered Lake Superior water was used for all rearing and testing. Dissolved oxygen, alkalinity, pH, and hardness were determined during the test by methods outlined by the American Public Health Association et al. (1975). Dissolved oxygen was greater than 95% saturation. Other measurements, including alkalinity (42 to 44 mg as CaCO_3), pH (7.6 to 7.8), and hardness (46 to 48 mg as CaCO_3) were similar to those described by Biesinger and Christensen (1972) for the same water source. All flow-through exposures were carried out at $15 \pm 0.6^\circ\text{C}$.

Exposure Procedures and Monitoring

Flow-Through Tests.—Ten animals of each species except *P. dorsata* (eight only for the fenvalerate exposure) were exposed in each duplicate chamber. All animals were exposed in either stainless-steel screen containers or glass and stainless-steel screen containers. The screen containers were suspended from the sides of the exposure chamber.

Static Test with Fenvalerate.—A static test was conducted in duplicate, using 50-ml beakers, each containing 30 ml of test water. The test water was taken from the flow-through test tanks and was changed daily. Ten juvenile amphipods (1 to 3 mm) were placed in each beaker, and the number affected or dead was recorded every 24 h. The test was conducted at 17°C .

Observations.—During the exposure period, all animals were observed daily for behavioral effects or death. Definite, sequential behavioral changes were established for several species. A three-step behavioral sequence was described for the mayfly *Ephemerella* sp. The first behavior to be affected was coordinated swimming; this loss was followed by a loss of leg response when prodded. The last response to be lost was spontaneous movement of the gills. For *Brachycentrus*, the first event was

the loss of the feeding position and being withdrawn into its case. The second event was the initiation of an action which could be called pawing. Legs of the larvae extended out of the case and continually moved in a pawing movement over the head. When this action stopped, the legs were often left extended out of the case. These animals did not feed, even if food was placed directly on the legs. The last behavioral event was leaving the case. These animals did not die immediately, but lay immobile on the bottom of the test chamber. The most difficult behavior to characterize was that associated with *Pteronarcys*. The first intoxication event was a loss of coordinated movement. The legs of the upright animal moved in a random manner, and directional progress was difficult. Often the animal twisted and twirled as it tried to move. The next stage was a loss of equilibrium. These animals would lie on their side or top and could not turn or right themselves even if aided with a gentle prod. The *Atherix* showed no obvious intoxication sequence, but the dead animals were often found fully extended. Snail condition was monitored by gently pouring the animals into a water-filled tray and observing movement. For all species, death was defined as a complete immobilization and failure of the animal to respond to a gentle prod. All animals were preserved and taxonomically verified at the end of the test.

Toxicant Preparation and Analysis

Technical-grade lot 80115 fenvalerate, which is the common name for Pydrin (SD-43775) [α -cyano-3-phenoxybenzyl-4-chloro- α -(1-methylethyl)-phenylacetate], was obtained from the Shell Chemical Co. Permethrin [3-phenoxybenzyl ($\pm$) *cis*, *trans* 3-(2,2-dichlorovinyl)2,2-dimethyl cyclopropane carboxylate] was obtained from ICI Corp. production lot no. 909, experimental purity. A saturated test solution was prepared for each chemical, using a modified water saturator (Veith and Comstock 1975) system. No solvents were used.

Samples for pesticide analysis were taken once a week from each exposure tank and analyzed by gas-chromatography by procedures described by Thompson (1974). To determine the accuracy of the extraction procedures, known amounts of each pesticide were added to a control-water sample before extraction. Mean percent recovery for the fenvalerate and permethrin water analyses were 108 ± 18 ($n = 19$) and 85 ± 17 ($n = 14$), respectively. All reported values are based on measured concentrations corrected for recovery.

Residue Analysis

At the end of the 28-day snail exposure to fenvalerate, survivors were rinsed in control water, the shell was removed, and the body was weighed and frozen until analyzed. Groups of three to five snails were used for the residue analysis, and a total of 16 groups were analyzed. After 4 days of exposure to permethrin, the immobilized stoneflies in the high concentrations were removed, rinsed in control water, weighed, and frozen for residue analysis. Four animals were pooled to produce one sample; five samples were analyzed.

Residue samples were extracted and analyzed with gas chromatography by procedures described by Thompson (1974). The accuracy of the extraction and analysis were checked by adding known amounts of fenvalerate or permethrin to a portion of the control samples. Recovery in the fenvalerate analysis was $99 \pm 1.6\%$, for permethrin the recovery was $73 \pm 0.9\%$. Bioconcentration factors (BCF) were determined by calculating the ratio of ng/g of animal (wet weight), divided by water concentration ($\mu\text{g/liter}$).

Data Analysis

In this study, the LC_{50} and EC_{50} values were determined by the trimmed Spearman-Kärber method (Hamilton et al. 1977) and are reported with 95% confidence limits.

Results

Fenvalerate

The amphipod *Gammarus* was the most sensitive species tested (Fig. 1A, 2). Within 5 h of the start of the exposure, all the adult-juvenile amphipods at $0.93 \mu\text{g/liter}$ were either immobilized or dead, and only 25% of the animals at $0.32 \mu\text{g/liter}$ showed gill movement. After 24 h of exposure, effects were seen at $0.12 \mu\text{g/liter}$ (Fig. 1). The exposure was continued for 12 days, but by day 6, only 35% of the animals survived at $0.022 \mu\text{g/liter}$. The LC_{50} values for the adult-juvenile exposures are shown on Fig. 2.

A static exposure was done with young amphipods (1 to 3 mm in length), and the results are also shown in

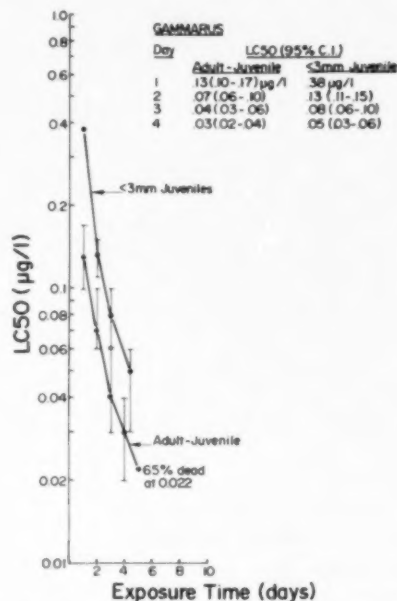


FIG. 2.—Relationship between median lethal concentration (LC_{50}) of fenvalerate and exposure time for *G. pseudolimnaeus*. Only juveniles <3 mm were tested under static conditions.

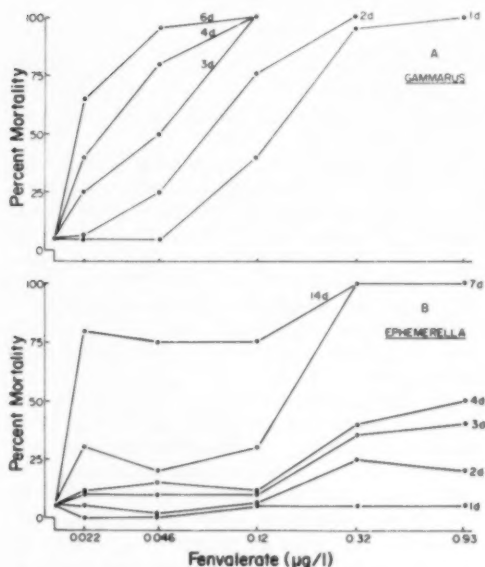


FIG. 1.—Effects of fenvalerate on survival of *G. pseudolimnaeus* and *Ephemerella* sp. after exposure for 1 to 14 days.

Fig. 2. Except at the 24-h exposure, the sensitivity of the young gammarids was similar to that found in exposure of adult juveniles.

The mayfly, *Ephemerella*, was more tolerant than *Gammarus* to fenvalerate. The lethal effects of the pesticide were not seen until day 4 (Fig. 1), when 50% of the animals had died at $0.93 \mu\text{g/liter}$. As the exposure time increased, death occurred at lower concentrations (Fig. 3). At 14 days, 80% of the animals were dead at $0.022 \mu\text{g/liter}$.

The toxicity-time patterns for *Atherix* are shown in Fig. 4 and 5. The lethal action of fenvalerate was seen by day 2 of exposure, and its lethal effects occurred at lower concentrations as the exposure time increased. Again, as with the gammarids and mayflies, no safe concentration was tested. The lowest concentration ($0.021 \mu\text{g/liter}$) resulted in a 30% mortality after 28 days of exposure (Fig. 4). The LC_{50} for the 28-day exposure was calculated to be $0.030 \mu\text{g/liter}$ (Fig. 5).

Two other animals, the stonefly *P. dorsata* and the snail *H. trivolvis*, were exposed to fenvalerate. Eight stoneflies were exposed at each of the five fenvalerate concentrations. Within 4 h, the stoneflies were lying on their sides and exhibited arched backs and random leg movement at $1.02 \mu\text{g/liter}$. At 24 h, all the stoneflies at 1.02 and 3 of the 8 (38%) at $0.44 \mu\text{g/liter}$ were immobilized. At 48 h, seven of the eight (88%) at $0.44 \mu\text{g/liter}$ and three of the eight (38%) at $0.17 \mu\text{g/liter}$ were immobile. The exposure was terminated at 72 h. At that time, three of the eight stoneflies (38%) at $0.11 \mu\text{g/liter}$ were immobile. At 72 h, 38 and 25% of the stoneflies

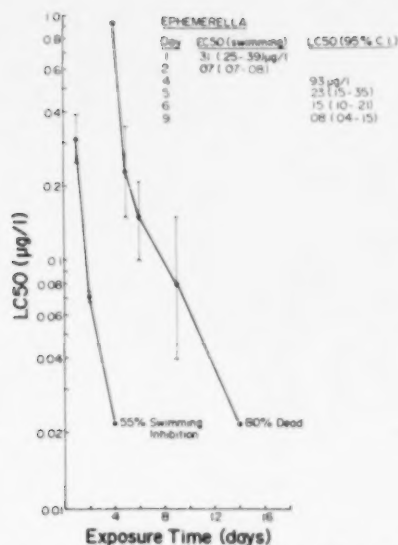


FIG. 3.—Relationship between median effect (EC_{50}) and lethal (LC_{50}) concentration of fenvalerate and exposure time for *Ephemereella* sp.

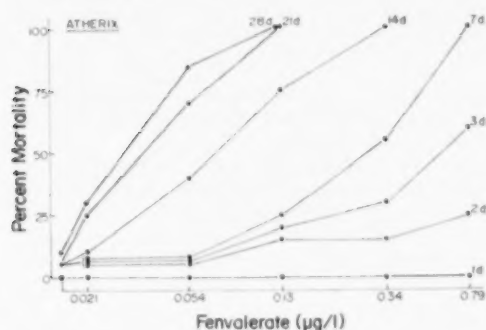


FIG. 4.—Effect of fenvalerate on survival of *Atherix* after exposure for 1 to 28 days.

were dead at 1.02 and 0.44 $\mu\text{g/liter}$. The 72-h immobilization EC_{50} and 95% confidence interval were 0.13 (0.09–0.17) $\mu\text{g/liter}$.

Residue

Snails exposed for 28 days to the highest exposure concentration of 0.79 $\mu\text{g/liter}$ did not show changes in behavior or survival. After removal of the shell and weighing, the snail tissue was analyzed and bioconcentration factors were calculated. The average bioconcentration factors ranged from 356 to 1,167 (Table 1).

Permethrin

The caddisfly *Brachycentrus* and the stonefly *P. dorsata* were exposed to permethrin for 28 days. The re-

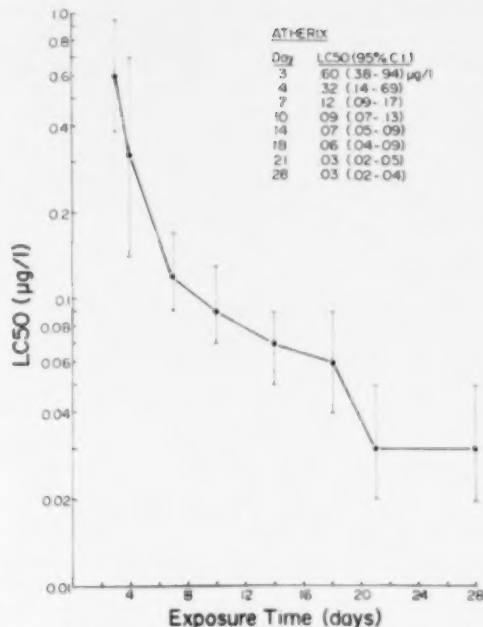


FIG. 5.—Relationship between median lethal concentration (LC_{50}) of fenvalerate and exposure time for *Atherix*.

Table 1.—Accumulation of fenvalerate in *H. trivoltis*

Water concn ($\mu\text{g/liter}$)	BCF $\bar{x} \pm 1 \text{ SD } (n)$
0.790	386 $\pm$ 159 (4)
0.345	356 $\pm$ 163 (4)
0.130	482 $\pm$ 24 (3)
0.054	592 $\pm$ 195 (3)
0.021	1,167 $\pm$ 168 (2)

sponse of *Brachycentrus* is shown in Fig. 6. Two events were observed. First, the animals behavior was radically changed by the pesticide. Within 6 h of exposure to 0.52 $\mu\text{g/liter}$, the exposed animals' behavior began to change (Fig. 6A), and by 24 h the behavior changes described above were evident in all animals. Within 2 days, the same behavioral changes occurred in all the animals at concentrations of 0.064 $\mu\text{g/liter}$ or greater. No behavioral changes were noted at the lowest concentration of 0.030 $\mu\text{g/liter}$.

The second event started on day 6 of exposure, when the animals began to die (Fig. 6B). In all cases, all the animals showed altered behavior before they died. With increasing exposure time, more deaths occurred at each concentration, until at 28 days of exposure 55% of the animals were dead at the lowest (0.030- $\mu\text{g/liter}$) concentration. The 21-day LC_{50} value was 0.17 (0.09–0.34) $\mu\text{g/liter}$. However, the data in Fig. 6 show that exposures as short as 48 h at 0.064 $\mu\text{g/liter}$ caused behavior changes in this caddisfly.

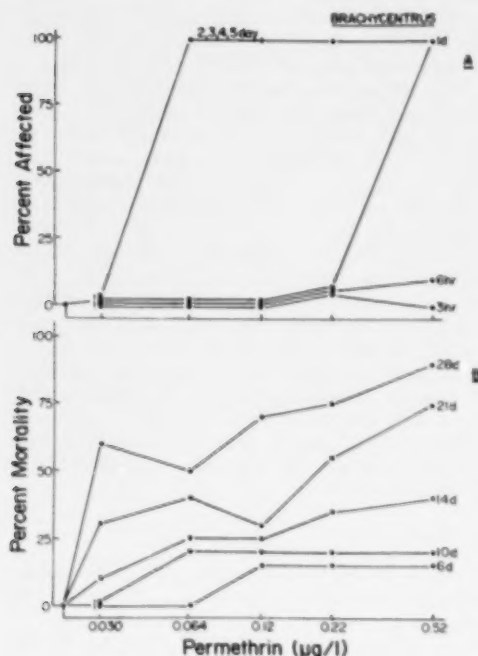


FIG. 6.—Effects of permethrin on behavior (A) and survival (B) of *B. americanus* after exposure for 3 h to 28 days.

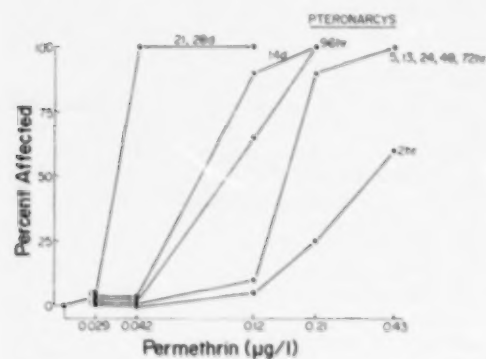


FIG. 7.—Effect of permethrin on behavior of *P. dorsata* after exposure for 2 h to 28 days.

The response of *P. dorsata* to an exposure of permethrin is shown in Fig. 7. The behavioral changes described above occurred rapidly at concentrations of 0.21 µg and greater per liter. Within 2 h 25% of the animals were immobilized, and within 5 h 90% were immobilized. Immobility at the next lower concentration did not occur until between 72 and 96 h. At 96 h, 65% were immobile at 0.12 µg/liter. Twenty-one days of exposure to 0.042 µg/liter resulted in all the animals being immobile. The lowest concentration, 0.029 µg/liter, did not affect the animals. Contrary to what was

found with *Brachycentrus*, the prolonged immobilization did not often result in death. The maximum death at any concentration was three animals. None were affected or died in the control.

Residue

Stonefly survivors of the permethrin exposures were analyzed for permethrin content. Ten groups were analyzed and the bioconcentration values ranged from 43 to 570 with an average of 183 and an SD of 171.

Discussion

Toxicity

The results of this study show that fenvalerate and permethrin can affect behavior and cause death for certain stream invertebrates at constant exposure concentrations of 0.022 and 0.030 µg/liter, respectively. However, a behavior change or mortality concentration statement has little meaning unless the concentration and the length of the exposure necessary to cause the specific event is considered. In the fenvalerate exposures, three sensitivities were seen. The most sensitive animals in this exposure were the amphipods. With both the adult-late-juvenile stage and the young (1 to 3 mm) amphipods, the toxic effects were seen within hours after the exposure started. The initial behavioral changes, such as loss of coordinated muscle control, were followed by death. Within 4 to 7 days, over 50% of the gammarids at the low concentration of 0.022 µg/liter were dead.

A second level of sensitivity was shown by the insects. These animals, compared with the amphipods, required a longer exposure time before death occurred. The LC_{50} value for the mayflies and *Atherix* had reached 0.16 and 0.12 µg/liter, respectively, in 7 days. By that time, well over 50% of the amphipods were dead at 0.022 µg/liter. By day 14, 80% of the mayflies were dead at 0.022 µg/liter. In comparison, 28 days of exposure were necessary to produce an LC_{50} of 0.029 µg/liter for *Atherix*.

The third sensitivity level was found with the snails. These animals were resistant to fenvalerate at 0.79 µg/liter during the 28-day exposure.

Exposures to low (0.029 to 0.52 µg/liter) concentrations of permethrin resulted in a response different than that found for exposure to similar concentrations of fenvalerate. With permethrin, death did not occur until late in the exposure. Lethal concentrations (LC_{50}) could not be calculated until day 21 of exposure for *Brachycentrus* and could not be calculated for the *Pteronarcys* exposures. However, simple observation of the animals in the test containers showed that long before death occurred both species were in distress (Fig. 6). Once the *Brachycentrus* started the "pawing" activity, all behavior associated with feeding and feeding itself stopped and was not resumed. The mortality shown in the last week of the exposure could be due to starvation resulting from this lack of feeding. A similar response was seen in the *Pteronarcys* exposures (Fig. 7). Once the exposed animals lost their equilibrium, the ability to feed was

severely reduced. The animals did not recover their feeding ability during the remainder of the exposure. Surprisingly, no more than three of the stoneflies died at each concentration during the exposure.

When behavioral changes become the major endpoints in a pesticide exposure, an obvious concern is the recovery of animals transferred to pesticide-free water. In a separate experiment, *Pteronarcys* were exposed to 0.44 µg of permethrin per liter for varying times up to 21 days. Although only four animals were removed at each sample time, some conclusions were evident. The stoneflies show considerable individual variation in their ability to recover from exposures to a given concentration of toxicant. The exposed animals transferred to clean water were usually upright within 24 h, and at 72 h either the recovery process was obviously underway or the animal died within a few days. Death could not be correlated with concentration or exposure time. The recovery of *Brachycentrus* was not examined.

An estimate of the impact of direct application of either fenvalerate or permethrin on natural systems cannot be obtained from either a direct application of laboratory data or from field experiments which do not correlate natural population conditions and the exposure concentration of the pesticide in the water. Since a coordinated field and laboratory data set for these chemicals is not available, only a broad estimate of the potential impacts can be made. Two approaches are evident. First because fenvalerate and permethrin are toxic to mosquitoes and blackflies, a comparison of laboratory toxic conditions between the target and nontarget animals would be useful. Second, an examination of the effects of applications of these pesticides at mosquito larvicide rates on natural populations may provide an effect estimate.

Most mosquito 24-h LC_{50} values for fenvalerate were between 0.9 and 5.5 µg/liter (Mulla et al. 1980). Exposure to these concentrations for 24 h could be harmful to the amphipods (Fig 2) used in this exposure. Because it is not possible to compare long exposures at low concentrations with short exposures at high concentrations, the effect on the three insect species is not as clear as with the amphipods. The best comparison is available for the stoneflies. These animals were behaviorally affected at 1.04 µg of fenvalerate per liter within about 4 h.

The 24-h LC_{50} values for six species of mosquitos exposed to permethrin range from 0.5 to 3.0 µg/liter (Mulla et al. 1980). This study did not include exposures of the nontarget animals to concentrations greater than 0.52 µg/liter. However, the data show that 100% of the *Pteronarcys* could be affected in less than 5 h at 0.43 µg/liter and within 24 h at 0.52 µg/liter for *Brachycentrus*.

Several reports (Mulla and Darwazeh 1976, Mulla et al. 1978a,b, and Mulla et al. 1980) have demonstrated lethal effects of both fenvalerate and permethrin on natural populations of nontarget invertebrates. The data from these reports show that mayflies were the most heavily affected insect when permethrin was applied at mosquito larvicide rates of 28 to 112 g/ha. Fenvalerate caused a reduction of mayflies (mostly baetids) at a rate (11.2 g/

ha) which would not control mosquitoes. No recovery was apparent for 24 days posttreatment. An application, by airplane, of permethrin at 70 g of AI/ha resulted in a dosing of a stream at about 13.4 g/ha (Kingsbury 1976). The major aquatic effect of this one-time dose was a 7.6-fold immediate increase in the drift of aquatic insects. The drift did not return to predose numbers until 24 to 36 h had passed. No effect was noted in the benthic populations measured with a Surber sample, and only a slight intoxication of caged and native fish was noted.

These reports show that application at mosquito larvicide rates can affect nontarget invertebrates in both ponds and streams. The persistence of these pesticides may produce unwanted nontarget mortality. The data in this study also show that, within hours of the start of the permethrin exposure, *Brachycentrus* and *Pteronarcys* behavior was affected. Although the relationship between drift and this behavior change has not been established, it is apparent that only a small amount of permethrin can affect behavior in the laboratory and in natural populations.

Residues

This study showed that *H. trivoltis* and *P. dorsata* accumulate fenvalerate and permethrin. The overall snail bioconcentration factor (BCF) for fenvalerate was 533 ± 294 with a range of 177 to 1,286. These values compare favorably with snail bioaccumulation values reported by Ohkawa et al. (1980) for radio-labelled fenvalerate. Their study was a 7- and 30-day exposure in a model ecosystem, and the BCF values ranged from 386 to 491. The overall stonefly BCF was 183 ± 171 , with a range of 43 to 570. There are no available BCF values for permethrin.

The results of this study show that fenvalerate and permethrin can be acutely toxic to nontarget macroinvertebrates at concentrations of 1 µg or less per liter. It also shows that even at the lowest concentrations tested (0.022 to 0.030 µg/liter), the pesticides are toxic if the exposure is extended to 7 to 14 days. The model ecosystem report (Ohkawa et al. 1980) showed that less than 2% of fenvalerate was desorbed from the soil particles during their test. This low rate of desorption coupled with physical and biological degradation may provide protection for the nontarget animals. However, because of the pesticide's high toxicity, application to water must be carefully considered to avoid unnecessary destruction of nontarget aquatic animals.

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